LINDHE'S

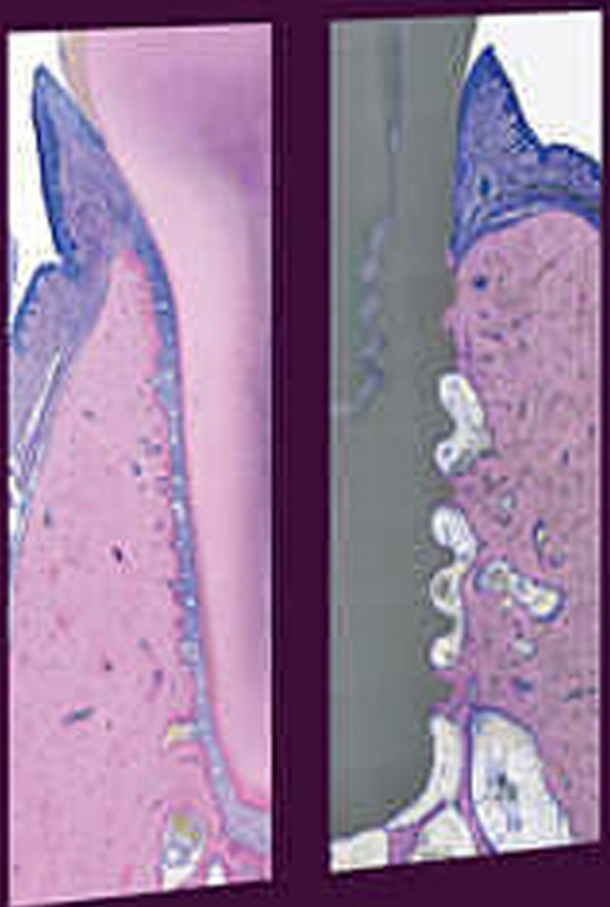
SEVENTH EDITION

Clinical Periodontology and Implant Dentistry

EDITED BY

Tord Berglundh, William V. Giannobile, Niklaus P. Lang, and Mariano Sanz

VOLUME 1



WILEY Blackwell

Lindhe's Clinical Periodontology and Implant Dentistry

Lindhe's Clinical Periodontology and Implant Dentistry

Seventh Edition

Edited by

Tord Berglundh
Department of Periodontology, Institute of Odontology,
The Sahlgrenska Academy at University of Gothenburg,
Gothenburg, Sweden

William V. Giannobile
Harvard School of Dental Medicine, Boston, MA, USA

Niklaus P. Lang
Department of Periodontology, School of Dental Medicine,
University of Bern, Bern, Switzerland

Mariano Sanz
Faculty of Odontology, ETEP (Etiology and Therapy of Periodontal and Peri-Implant Diseases) Research Group, Complutense University of Madrid, Madrid, Spain and Department of Periodontology, Faculty of Dentistry, Institute of Clinical Dentistry,
University of Oslo, Oslo, Norway

WILEY Blackwell

Volume 1
BASIC CONCEPTS

This edition first published 2022
© 2022 by John Wiley & Sons Ltd
© 2015 by John Wiley & Sons Ltd
© 2003, 2008 by Blackwell Munksgaard
© 1983, 1989, 1997 by Munksgaard

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at http://www.wiley.com/go/permissions.

The right of Tord Berglundh, William V. Giannobile, Niklaus P. Lang and Mariano Sanz to be identified as the authors of the editorial material in this work has been asserted in accordance with law.

Registered Offices
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office
9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Limit of Liability/Disclaimer of Warranty
The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting scientific method, diagnosis, or treatment by physicians for any particular patient. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist where appropriate. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

Library of Congress Cataloging-in-Publication Data

Names: Berglundh, Tord, 1954– editor. | Giannobile, William V., editor. | Lang, Niklaus Peter, editor. | Sanz, Mariano (Professor) editor.
Title: Lindhe's clinical periodontology and implant dentistry / edited by Tord Berglundh, William V. Giannobile, Niklaus P. Lang, Mariano Sanz.
Other titles: Clinical periodontology and implant dentistry
Description: Seventh edition. | Hoboken : John Wiley & Sons, Inc., 2022. | Preceded by Clinical periodontology and implant dentistry / edited by Jan Lindhe and Niklaus P. Lang ; associate editors, Tord Berglundh, William V. Giannobile, Mariano Sanz. 6th edition. 2015.
Identifiers: LCCN 2021028065 (print) | LCCN 2021028066 (ebook) | ISBN 9781119438885 (cloth) | ISBN 9781119438946 (adobe pdf) | ISBN 9781119438953 (epub)
Subjects: MESH: Periodontal Diseases | Dental Implantation | Dental Implants
Classification: LCC RK667.I45 (print) | LCC RK667.I45 (ebook) | NLM WU 240 | DDC 617.6/93–dc23
LC record available at https://lccn.loc.gov/2021028065
LC ebook record available at https://lccn.loc.gov/2021028066

Cover Design: Wiley
Cover Image: Courtesy of Niklaus P. Lang

Set in 9.5/12pt Palatino by Straive, Pondicherry, India

10 9 8 7 6 5 4 3 2 1

Contents

Volume 2: CLINICAL CONCEPTS

Part 14: Surgery for Implant Installation

Part 15: Reconstructive Ridge Therapy

Part 16: Occlusal and Prosthetic Therapy

Contributors

Maurício Araújo
Department of Dentistry
State University of Maringá
Maringá
Paraná
Brazil

Gustavo Avila-Ortiz
Department of Periodontics
College of Dentistry
University of Iowa
Iowa City
IA
USA

Hans-Rudolf Baur
Department of Cardiology
Medical School
University of Bern
Bern
Switzerland

James Beck
Division of Comprehensive Oral Health/
Periodontology
Adams School of Dentistry
University of North Carolina
Chapel Hill
NC
USA

Tord Berglundh
Department of Periodontology
Institute of Odontology
The Sahlgrenska Academy at University of
Gothenburg
Gothenburg
Sweden

Michael M. Bornstein
Oral and Maxillofacial Radiology
Applied Oral Sciences & Community Dental Care
Faculty of Dentistry
The University of Hong Kong
Hong Kong SAR
China, and
Department of Oral Health & Medicine
University Center for Dental Medicine Basel UZB
University of Basel
Basel
Switzerland

Dieter D. Bosshardt
Department of Periodontology
School of Dental Medicine
University of Bern
Bern
Switzerland

Rino Burkhardt
Faculty of Dentistry
The University of Hong Kong
Hong Kong SAR
China, and
Clinic of Reconstructive Dentistry
University of Zurich
Zurich
Switzerland

Iain Chapple
Periodontal Research Group
School of Dentistry
University of Birmingham
Birmingham
UK

Lyndon F. Cooper
University of Illinois at Chicago
College of Dentistry
Chicago
IL
USA

Pierpaolo Cortellini
European Research Group on Periodontology
(ERGOPerio)
Genoa
Italy
and
Private Practice
Florence
Italy

Mike Curtis
Faculty of Dentistry
Oral and Craniofacial Sciences
King's College London
London
UK

Dorothea Dagassan-Berndt
Center for Dental Imaging
University Center for Dental Medicine Basel UZB
University of Basel
Basel
Switzerland

Francesco D'Aiuto
Periodontology Unit
UCL Eastman Dental Institute
London
UK

Ryan T. Demmer
Division of Epidemiology and Community Health
School of Public Health
University of Minnesota
Minneapolis
MN
USA

Jan Derks
Department of Periodontology
Institute of Odontology
The Sahlgrenska Academy at University of Gothenburg
Gothenburg
Sweden

Massimo de Sanctis
Department of Periodontology
Università Vita e Salute San Raffaele
Milan
Italy

Peter Eickholz
Department of Periodontology
Center of Dentistry and Oral Medicine (Carolinum)
Johann Wolfgang Goethe-University Frankfurt
am Main
Frankfurt am Main
Germany

Roberto Farina
Research Centre for the Study of Periodontal and
Peri-implant Diseases
University of Ferrara
Ferrara
Italy, and
Operative Unit of Dentistry
Azienda Unità Sanitaria Locale (AUSL)
Ferrara
Italy

Magda Feres
Department of Periodontology
Dental Research Division
Guarulhos University
Guarulhos
São Paulo
Brazil, and
The Forsyth Institute
Cambridge
MA
USA

William V. Giannobile
Harvard School of Dental Medicine
Boston
MA
USA

Filippo Graziani
Department of Surgical, Medical and Molecular
Pathology and Critical Care Medicine
University of Pisa
Pisa
Italy

Christoph H.F. Hämmerle
Clinic of Reconstructive Dentistry
Center of Dental Medicine
University of Zurich
Zurich
Switzerland

Hatice Hasturk
Forsyth Institute
Cambridge
MA
USA

Lisa Heitz-Mayfield
International Research Collaborative – Oral Health and
Equity
School of Anatomy, Physiology and Human Biology
The University of Western Australia
Crawley
WA
Australia

David Herrera
ETEP (Etiology and Therapy of Periodontal and
Peri-Implant Diseases) Research Group
Complutense University of Madrid
Madrid
Spain

Palle Holmstrup
Department of Periodontology
School of Dentistry
University of Copenhagen
Copenhagen
Denmark

Kuofeng Hung
Oral and Maxillofacial Radiology
Applied Oral Sciences & Community Dental Care
Faculty of Dentistry
The University of Hong Kong
Hong Kong SAR
China

Saso Ivanovski
School of Dentistry
The University of Queensland
Australia

Søren Jepsen
Department of Periodontology, Operative, and
Preventive Dentistry
Center of Oral, Dental, Maxillofacial Medicine
University of Bonn
Bonn
Germany

Mats Jontell
Oral Medicine and Pathology
Institute of Odontology
The Sahlgrenska Academy at University of Gothenburg
Gothenburg
Sweden

Ronald. E. Jung
Clinic of Reconstructive Dentistry
University of Zurich
Zurich
Switzerland

Darnell Kaigler
Department of Periodontics and Oral Medicine
University of Michigan School of Dentistry
and
Department of Biomedical Engineering
College of Engineering
Ann Arbor
MI
USA

Alpdogan Kantarci
Forsyth Institute
Cambridge
MA
USA

Janet Kinney
Department of Periodontics and Oral Medicine
University of Michigan School of Dentistry
Ann Arbor
MI
USA

Kenneth Kornman
Department of Periodontics and Oral Medicine
University of Michigan School of Dentistry
Ann Arbor
MI
USA

Marja L. Laine
Department of Periodontology
Academic Center for Dentistry Amsterdam (ACTA)
University of Amsterdam and Vrije Universiteit Amsterdam
Amsterdam
The Netherlands

Evanthia Lalla
Division of Periodontics
Section of Oral, Diagnostic, and Rehabilitation Sciences
Columbia University College of Dental Medicine
New York
NY
USA

Niklaus P. Lang
Department of Periodontology
School of Dental Medicine
University of Bern
Bern
Switzerland

Jan Lindhe
Department of Periodontology
Institute of Odontology
The Sahlgrenska Academy at University of Gothenburg
Gothenburg
Sweden

Bruno G. Loos
Department of Periodontology
Academic Center for Dentistry Amsterdam (ACTA)
University of Amsterdam and Vrije Universiteit
Amsterdam
Amsterdam
The Netherlands

Philip D. Marsh
Department of Oral Biology
School of Dentistry
University of Leeds
UK

Conchita Martin
Faculty of Odontology
Complutense University of Madrid
Madrid
Spain

Giedrė Matulienė
Private Practice
Zurich
Switzerland

Luigi Nibali
Department of Periodontology
Centre for Host–Microbiome Interactions
King's College London
Guy's Hospital
London
UK

Sture Nyman (deceased)
Department of Periodontology
Institute of Odontology
The Sahlgrenska Academy at University of Gothenburg
Gothenburg
Sweden

Panos N. Papapanou
Division of Periodontics
Section of Oral, Diagnostic, and Rehabilitation Sciences
Columbia University College of Dental Medicine
New York
NY
USA

Bjarni E. Pjetursson
Department of Reconstructive Dentistry
University of Iceland
Reykjavik
Iceland

Christoph A. Ramseier
Department of Periodontology
School of Dental Medicine
University of Bern
Bern
Switzerland

Giulio Rasperini
Department of Biomedical, Surgical, and Dental Sciences
Foundation IRCCS Ca' Granda Polyclinic
University of Milan
Milan
Italy

Giovanni E. Salvi
Department of Periodontology
School of Dental Medicine
University of Bern
Bern
Switzerland

Mariano Sanz
Faculty of Odontology
ETEP (Etiology and Therapy of Periodontal and
Peri-Implant Diseases) Research Group
Complutense University of Madrid
Madrid
Spain, and
Department of Periodontology
Faculty of Dentistry
Institute of Clinical Dentistry
University of Oslo
Oslo
Norway

Arne S. Schaefer
Department of Periodontology, Oral Medicine and Oral Surgery
Institute for Dental and Craniofacial Sciences
Charité–Universitätsmedizin
Berlin
Germany

Frank Schwarz
Department of Oral Surgery and Implantology
Centre for Dentistry and Oral Medicine
Frankfurt
Germany

Anton Sculean
Department of Periodontology
School of Dental Medicine
University of Bern
Bern
Switzerland

Jorge Serrano
ETEP (Etiology and Therapy of Periodontal and Peri-Implant Diseases) Research Group
Complutense University of Madrid
Madrid
Spain

Gregory J. Seymour
School of Dentistry
The University of Queensland
Brisbane
Australia

Dagmar Else Slot
Department of Periodontology
Academic Centre for Dentistry Amsterdam (ACTA)
University of Amsterdam and Vrije Universiteit Amsterdam
Amsterdam
The Netherlands

Clark M. Stanford
University of Illinois at Chicago
College of Dentistry
Chicago
IL, USA

Franz J. Strauss
Clinic of Reconstructive Dentistry
University of Zurich
Zurich
Switzerland, and
Department of Conservative Dentistry
Faculty of Dentistry
University of Chile
Santiago
Chile

Jeanie E. Suvan
Unit of Periodontology
UCL Eastman Dental Institute
London
UK

Dimitris N. Tatakis
Division of Periodontology
Ohio State University
College of Dentistry
Columbus
OH
USA

Daniel S. Thoma
Clinic of Reconstructive Dentistry
University of Zurich
Zurich
Switzerland

Cristiano Tomasi
Department of Periodontology
Institute of Odontology
The Sahlgrenska Academy at University of Gothenburg
Gothenburg
Sweden

Maurizio S. Tonetti
Shanghai Jiao Tong University School of Medicine
and
Clinical Research Center of Periodontology and Oral and Maxillo-facial Implants, National Clinical Research Center of Oral Diseases and Medical Clinical Research Center
Shanghai 9th People Hospital
China, and
ERGOPerio (European Research Group on Periodontology)
Genova
Italy

Leonardo Trombelli
Research Centre for the Study of Periodontal and Peri-implant Diseases
University of Ferrara
Ferrara
Italy, and
Operative Unit of Dentistry
Azienda Unità Sanitaria Locale (AUSL)
Ferrara
Italy

Ubele van der Velden
Department of Periodontology
Academic Center for Dentistry Amsterdam (ACTA)
University of Amsterdam and Vrije Universiteit Amsterdam
Amsterdam
The Netherlands

Fridus van der Weijden
Department of Periodontology
Academic Centre for Dentistry Amsterdam (ACTA)
University of Amsterdam and Vrije Universiteit
Amsterdam
Amsterdam
The Netherlands

Fabio Vignoletti
Department of Periodontology
Faculty of Odontology
Complutense University of Madrid
Madrid
Spain

Jan L. Wennström
Department of Periodontology
Institute of Odontology
The Sahlgrenska Academy at University of Gothenburg
Gothenburg
Sweden

Preface

In 1983, Professor Jan Lindhe, University of Gothenburg, Sweden, published the first edition of *Clinical Periodontology*. This was only 2 years after the publication of a textbook on clinical periodontology in Scandinavian languages. It was a pioneer enterprise and began a new era in the study of periodontology. Up to this point, the profession was predominantly oriented towards a treatment philosophy that was based on *deductive thinking*, and very little scientific evidence had been presented.

In this light, the publication of a textbook that was based on *inductive thinking* and hypothesis testing was a true milestone and represented a novelty in teaching undergraduate and graduate students. As the field of clinical periodontology evolved, and more evidence arose from both clinical and preclinical studies, the textbook had to be revised on a regular basis. By and large, every 5 to 8 years a new edition of *Clinical Periodontology* was put together. With every edition, efforts were made to expand the circle of authors in order to obtain more information on evidence-based concepts. The textbook thus became the most internationally recognized source of information in the periodontal community.

About 20–30 years ago, implant dentistry had become an integral part of clinical periodontology. Hence, the fifth edition of *Clinical Periodontology* was substantially expanded to incorporate biological and clinical aspects of implant dentistry. As teeth and implants are to function together as separate or connected units in the same dentition, a profound knowledge of the biology of the tissues surrounding the tooth and the dental implant is of utmost importance. Owing to the large volume of new information, the fifth edition of the now titled *Clinical Periodontology and Implant Dentistry* was split into two volumes, one on *basic concepts* and another on *clinical concepts*. This division into two volumes was maintained for the sixth edition and is also maintained for this, the seventh edition.

In the last 35 years, during which the textbook evolved into the most popular source of reference, periodontology and implant dentistry have become clinical disciplines based on sound scientific evidence. As a new classification of periodontal and peri-implant diseases and conditions emerged after a world workshop staged by the American Academy of Periodontology and the European Federation of Periodontology, it was time, again, to update the textbook.

In this edition, over 90% of the content has been thoroughly revised and condensed for better understanding. Some less essential chapters have been eliminated and others merged to make the text more cohesive. A new and younger generation of authors of international reputation have been invited to contribute. Moreover, the team of Editors has been enlarged to four.

It is our hope that *Lindhe's Clinical Periodontology and Implant Dentistry* remains the key book of reference to guide treatment planning according to sound biological and evidence-based principles rather than opinions based on trial and error philosophies.

Tord Berglundh
William V. Giannobile
Niklaus P. Lang
Mariano Sanz

March 2021

Part 1: Anatomy

Chapter 1

Anatomy and Histology of Periodontal Tissues

Dieter D. Bosshardt[1], Jan Lindhe[2], Niklaus P. Lang[1], and Maurício Araújo[3]

[1] Department of Periodontology, School of Dental Medicine, University of Bern, Bern, Switzerland
[2] Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden
[3] Department of Dentistry, State University of Maringá, Maringá, Paraná, Brazil

Introduction

This chapter provides a brief description of the characteristics of the normal periodontium. It is assumed that the reader has prior knowledge of oral embryology and histology.

The periodontium (peri = around, odontos = tooth) comprises the following tissues: (1) *gingiva*, (2) *periodontal ligament*, (3) *root cementum*, and (4) *alveolar bone proper* (Fig. 1-1). The latter lines the alveolus of the tooth and is continuous with the alveolar bone; on a radiograph it can be called *lamina dura*. The *alveolar process* that extends from the basal bone of the maxilla and mandible consists of the alveolar bone and the *alveolar bone proper*.

The main function of the periodontium is to attach the tooth to the jaw bone and to maintain the integrity of the surface of the masticatory mucosa of the oral cavity. The periodontal ligament, root cementum, and alveolar bone proper, may together be called "the attachment apparatus" or "the supporting tissues of the teeth", constituting a developmental, biologic, and functional unit which undergoes certain changes with age and is, in addition, subjected to morphologic changes related to functional alterations and alterations in the oral environment.

The development of the periodontal tissues occurs during the development and formation of teeth. This process starts early in the embryonic phase when cells from the neural crest (from the neural tube of the embryo) migrate into the first branchial arch. In this position, the neural crest cells form a band of *ectomesenchyme* beneath the epithelium of the stomatodeum (the primitive oral cavity). After the uncommitted neural crest cells have reached their location in the jaw space, the epithelium of the stomatodeum releases factors which initiate epithelial–ectomesenchymal interactions. Once these interactions have occurred, the ectomesenchyme takes the dominant role in the further development. Following the formation of the *dental lamina*, a series of processes are initiated (bud stage, cap stage, bell stage, and root development) which result in the formation of a tooth and its surrounding periodontal tissues, including the alveolar bone proper. During the cap stage, condensation of ectomesenchymal cells appears in relation to the dental epithelium (the dental organ), forming the *dental papilla* that gives rise to

Lindhe's Clinical Periodontology and Implant Dentistry, Seventh Edition. Edited by Tord Berglundh, William V. Giannobile, Niklaus P. Lang, and Mariano Sanz.
© 2022 John Wiley & Sons Ltd. Published 2022 by John Wiley & Sons Ltd.

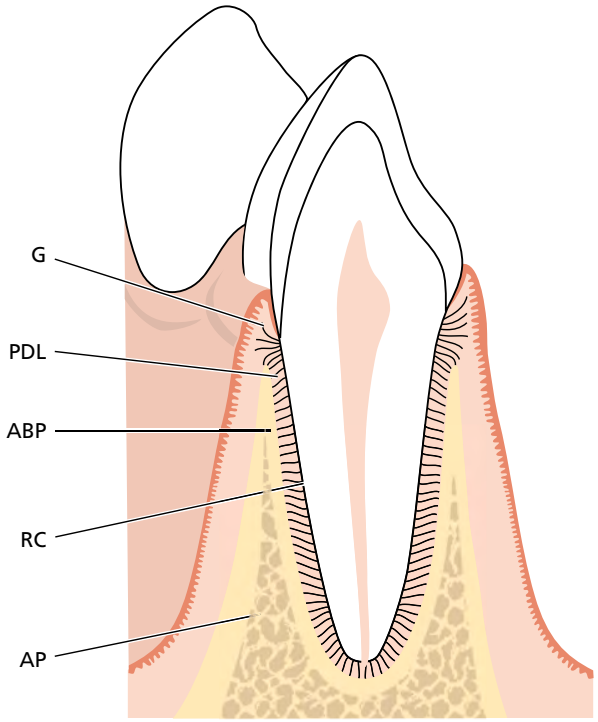


Fig. 1-1 A tooth and its periodontal tissues consisting of gingiva (G), periodontal ligament (PDL), alveolar bone proper (ABP), and root cementum (RC). AP, alveolar process.

Fig. 1-2 Light micrograph of a tooth germ at the cap stage with the dental organ (DO), the dental papilla (DP), and the dental follicle (DF).

the dentin and the pulp, and the *dental follicle* that gives rise to the periodontal supporting tissues (Fig. 1-2). The decisive role played by the ectomesenchyme in this process is further established by the fact that the tissue of the dental papilla apparently also determines the shape and form of the tooth.

If a tooth germ in the bell stage of development is dissected and transplanted to an ectopic site (e.g. the connective tissue of the anterior chamber of the eye), the tooth formation process continues. The crown and the root are formed, and the supporting structures (i.e. cementum, periodontal ligament, and a thin lamina of alveolar bone proper) also develop. Such experiments document that all information necessary for the formation of a tooth and its attachment apparatus resides within the tissues of the dental organ and the surrounding ectomesenchyme. The dental organ is the formative organ of enamel, the dental papilla is the formative organ of the dentin–pulp complex, and the dental follicle is the formative organ of the attachment apparatus (cementum, periodontal ligament, and alveolar bone proper).

The development of the root and the periodontal supporting tissues follows that of the crown. Epithelial cells of the external and internal dental epithelium (the dental organ) proliferate in an apical direction, forming a double layer of cells called *Hertwig's epithelial root sheath*. The odontoblasts forming the dentin of the root differentiate from ectomesenchymal cells in the dental papilla under the inductive influence of the inner epithelial cells (Fig. 1-3). The dentin continues to form in an apical direction, producing the framework of the root. During formation of the root, the periodontal supporting tissues including the acellular extrinsic fiber cementum (AEFC) develop. Some of the events in cementogenesis are still unclear, but the following concept is now generally accepted.

At the start of root dentin formation, the inner cells of Hertwig's epithelial root sheath may synthesize and secrete enamel-related proteins, some of which belong to the amelogenin family. At the end of this process, the epithelial root sheath becomes fenestrated and ectomesenchymal cells from the dental follicle penetrate through these fenestrations and contact the root surface. The ectomesenchymal cells in contact with the root surface differentiate into cementoblasts and start to form cementoid. This cementoid represents the organic matrix of the cementum and consists of a ground substance and collagen fibers, which intermingle with collagen fibers in the not yet fully mineralized outer layer of the dentin. It is assumed that the cementum becomes firmly attached to the dentin through these fiber interactions followed by mineralization of this interface (Fig. 1-4). The formation of the CIFC, which often covers the apical third of the dental roots, differs from that of AEFC

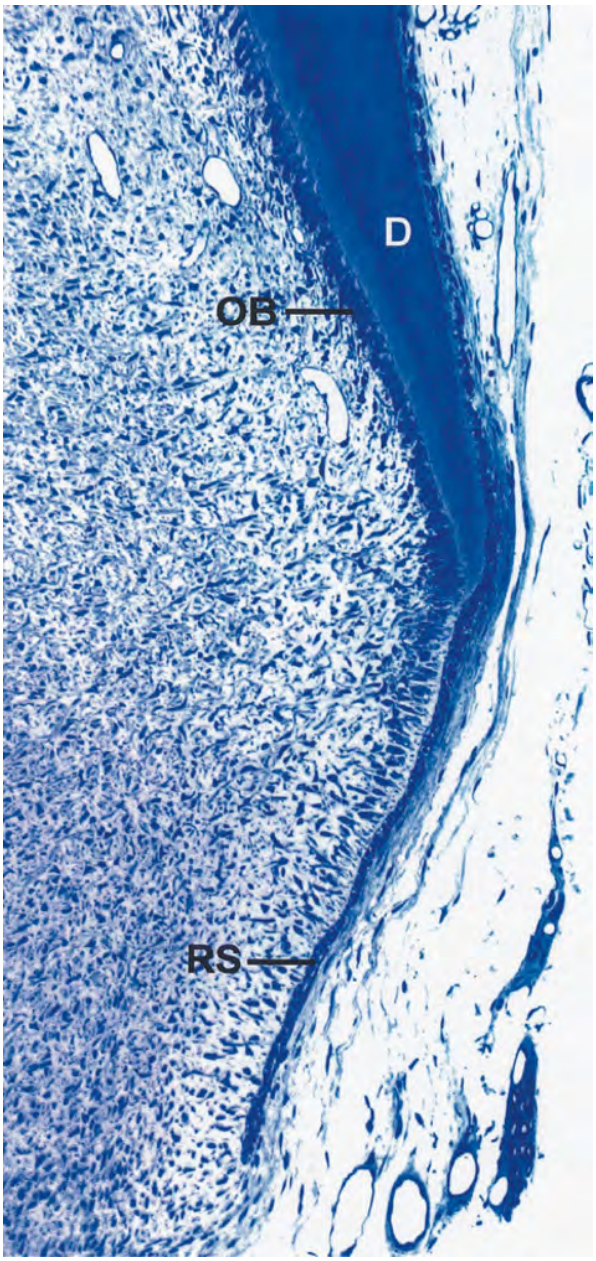


Fig. 1-3 Light micrograph illustrating the edge of a developing tooth root with the Hertwig's epithelial root sheath (RS), odontoblasts (OB), and dentin (D).

as some of the cementoblasts become embedded in the cementum.

The remaining parts of the periodontium are formed by ectomesenchymal cells from the dental follicle lateral to the cementum. Some of them differentiate into periodontal ligament fibroblasts and form the fibers of the periodontal ligament, while others become osteoblasts and form the alveolar bone proper in which the periodontal fibers are anchored. This bony structure has also been term "*bundle bone*". In other words, the bundle bone is also an ectomesenchymal product. It is likely, but still not conclusively documented, that ectomesenchymal cells remain in the mature periodontium and take part in the turnover of this tissue.

Gingiva

Anatomy

The oral mucosa is continuous with the skin of the lips and the mucosa of the soft palate and pharynx. The oral mucosa consists of: (1) the *masticatory mucosa*, which includes the gingiva and the covering of the hard palate; (2) the *specialized mucosa*, which covers the dorsum of the tongue; and (3) the remaining part, called the *lining mucosa*.

The gingiva is that part of the masticatory mucosa which covers the alveolar process and surrounds the cervical portion of the teeth (Fig. 1-5). It consists of an epithelial layer and an underlying connective tissue layer called the *lamina propria*. The gingiva obtains its final shape and texture in conjunction with eruption of the teeth.

In the coronal direction, the coral pink gingiva terminates in the *free gingival margin*, which has a scalloped outline. In the apical direction, the gingiva is continuous with the loose, darker red *alveolar mucosa* (lining mucosa) from which the gingiva is separated by a usually easily recognizable border called either the mucogingival junction, sometimes termed the mucogingival line (Fig. 1-5, arrows). As the hard palate and maxillary alveolar process are covered by a keratinizing mucosa of similar clinical appearance, no mucogingival junction is macroscopically recognizable (Fig. 1-6).

Two parts of the gingiva may be identified (Fig. 1-7): (1) the free gingiva and (2) the attached gingiva. The free gingiva is coral pink, has a dull surface and a firm consistency. It comprises the gingival tissue at the vestibular and lingual/palatal aspects of the teeth. On the vestibular and lingual sides of the teeth, the free gingiva extends from the gingival margin in an apical direction to a structure named *free gingival groove*, which is only observable in approximately one-third of the cases. The attached gingiva is demarcated by the mucogingival junction in the apical direction.

The free gingival margin is often rounded in such a way that a small invagination or sulcus is formed between the tooth and the gingiva. When a periodontal probe is inserted into this invagination and, further apically, towards the cementoenamel junction (CEJ), the gingival tissue is separated from the tooth and a "*gingival pocket*" or "*gingival crevice*" is artificially opened (Fig. 1-8). Thus, in clinically healthy gingiva, there is in fact no "gingival pocket" or "gingival crevice" present, but the gingiva is in close contact with the enamel surface. After complete tooth eruption, the free gingival margin is located on the enamel surface approximately 1.5–2 mm coronal to the CEJ.

The shape of the *interdental gingiva (the interdental papilla)* is determined by the contact relationships between the teeth, the width of the approximal tooth

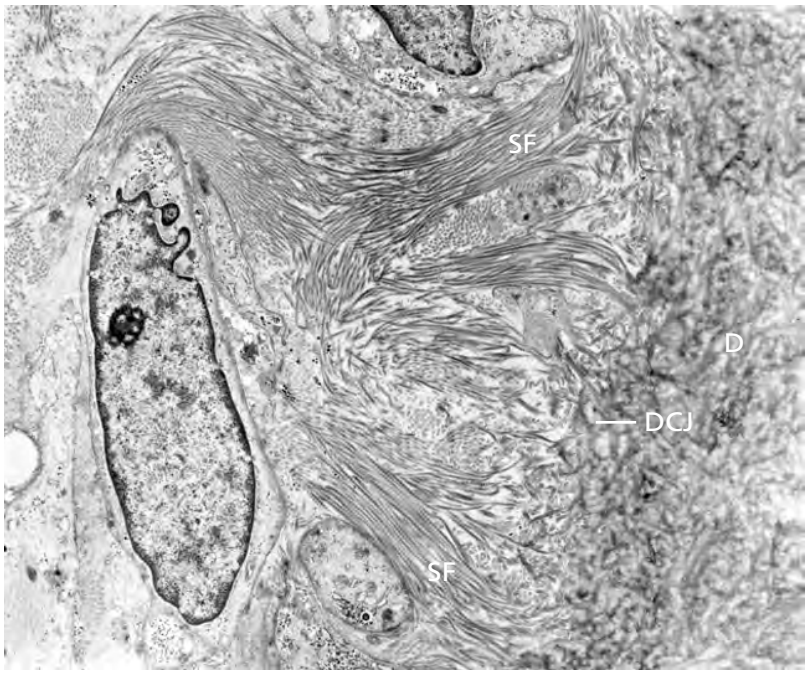


Fig. 1-4 Transmission electron micrograph illustrating the attachment of the future Sharpey's fibers (SF) to the root dentin (D) at a time where the mineralization has reached the dentinocemental junction (DCJ).

Fig. 1-5 Frontal view of the masticatory and lining mucosa. The arrows indicate the mucogingival junction, sometimes also called the mucogingival line.

Fig. 1-6 Masticatory mucosa lining the hard palate. There is no mucogingival line present in the palate, because the hard palate and the maxillary alveolar process are covered by the same type of masticatory mucosa.

surfaces, and the course of the CEJ. In anterior regions of the dentition, the interdental papilla is of pyramidal shape (Fig. 1-9a), while in the molar regions, the papillae are flatter in the buccolingual direction (Fig. 1-9b). Due to the presence of interdental papillae, the free gingival margin follows a more or less accentuated, scalloped course through the dentition.

The interdental region in premolar and molar teeth has two papillae, a vestibular (VP) and a lingual/palatal (LP) papilla, separated by the col region. The col region is lined by a thin non-keratinized epithelium (Fig. 1-10). This epithelium has many features in common with the junctional epithelium.

The attached gingiva is demarcated in the coronal direction by the free gingival groove (Fig. 1-11) or, when such a groove is not present, by a horizontal plane placed at the level of the CEJ. In clinical examinations, it was observed that a free gingival groove is only present in about 30–40% of adults. The free gingival groove is often most pronounced on the vestibular aspect of the teeth, occurring most frequently in the incisor and premolar regions of the mandible, and least frequently in the mandibular molar and maxillary premolar regions.

The attached gingiva extends in the apical direction to the mucogingival junction, where it becomes continuous with the alveolar (lining) mucosa. It is of firm texture, coral pink in color, and often shows small depressions on the surface. The depressions, called "stippling", give the appearance of orange peel. The gingiva is firmly attached to the underlying alveolar bone and cementum by connective

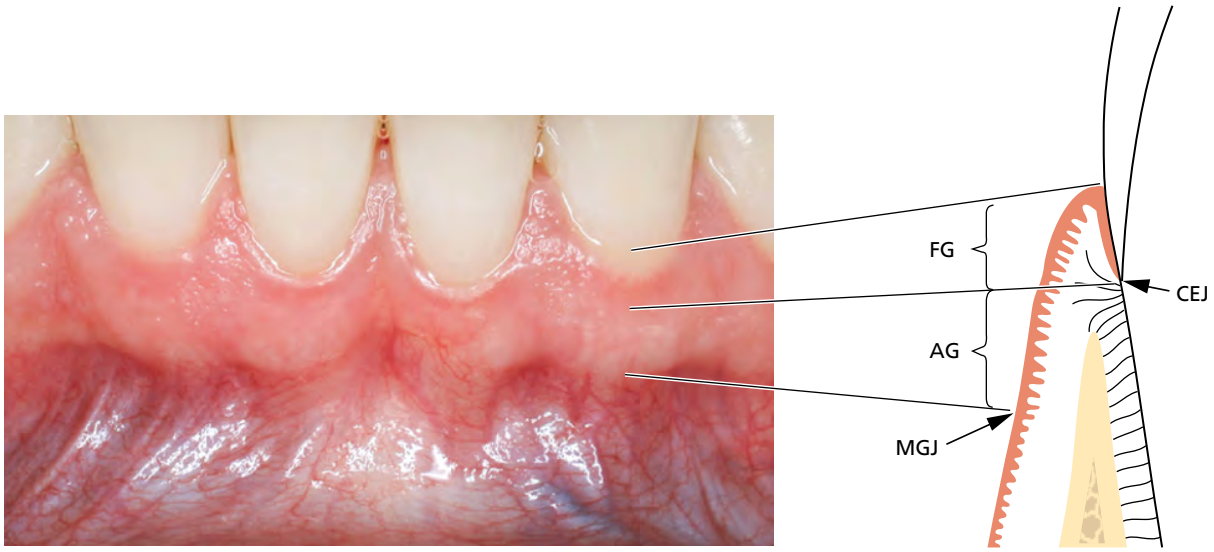


Fig. 1-7 Three parts of the gingiva can be identified: the free gingiva (FG), the interdental gingiva, and the attached gingiva (AG). The mucogingival junction (MGJ) demarcates the gingiva from the alveolar mucosa. CEJ, cementoenamel junction.

Fig. 1-8 A periodontal probe has been inserted into a clinically healthy tooth–gingiva interface and a "gingival crevice" was artificially opened approximately to the level of the cementoenamel junction.

tissue fibers, and is, therefore, comparatively immobile in relation to the underlying tissue. The darker red alveolar mucosa located apical to the mucogingival junction, on the other hand, is loosely bound to the underlying bone. Therefore, in contrast to the attached gingiva, the alveolar mucosa is mobile in relation to the underlying tissue and hence belongs to the lining mucosa.

The width of the gingiva varies in size in different parts of the dentition. In the maxilla (Fig. 1-12a), the vestibular gingiva is generally widest in the area of the incisors and narrowest adjacent to the premolars. In the mandible (Fig. 1-12b), the gingiva on the lingual aspect is particularly narrow in the area of the incisors and wide in the molar region. The range of variation is 1–9 mm. In the mandibular premolar region, the gingiva is extremely narrow (Fig. 1-13).

The result of a study in which the width of the attached gingiva was assessed and related to the

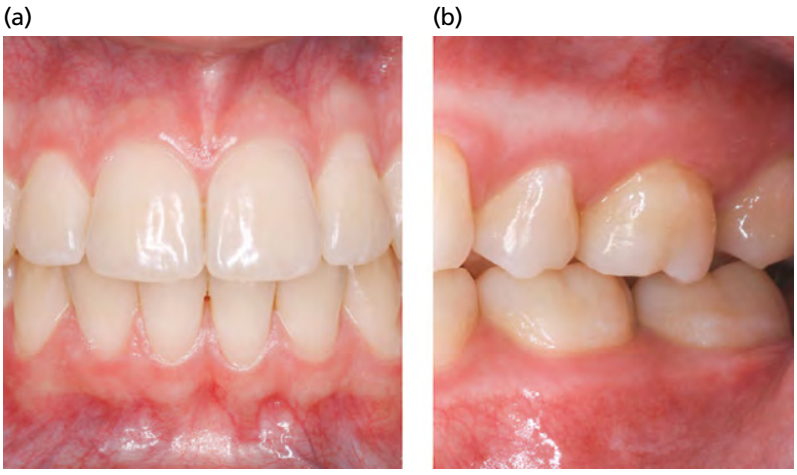


Fig. 1-9 Frontal view showing the shape of the interdental papillae in the anterior (a) and premolar/molar (b) regions.

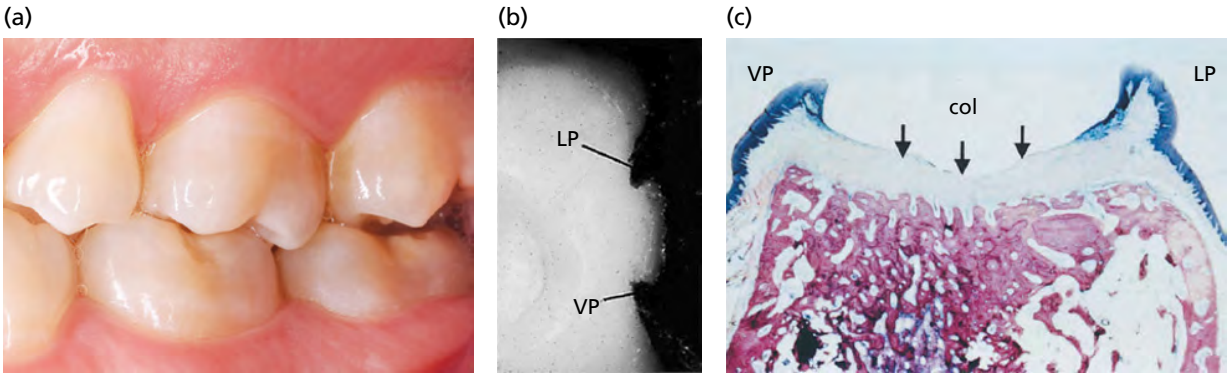


Fig. 1-10 (a) Premolar/molar regions of the dentition exhibit an approximal contact surface. (b) After removal of the distal tooth, a col can be seen between the vestibular (VP) and lingual papillae (LP). (c) Histologically, the bucco-oral section of the col region (arrows) demonstrates a thin non-keratinizing lining between the two papillae.

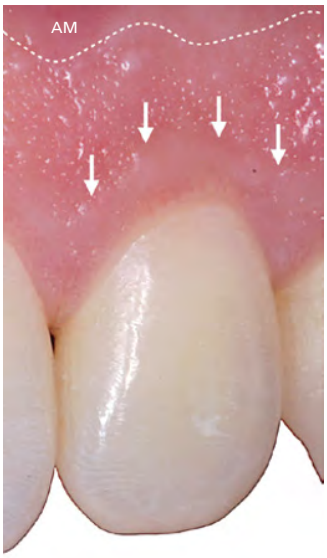


Fig. 1-11 Clinical view on the mucosal tissues. The mucogingival junction (arrows) demarcates the gingiva (masticatory mucosa) from the alveolar (lining) mucosa (AM).

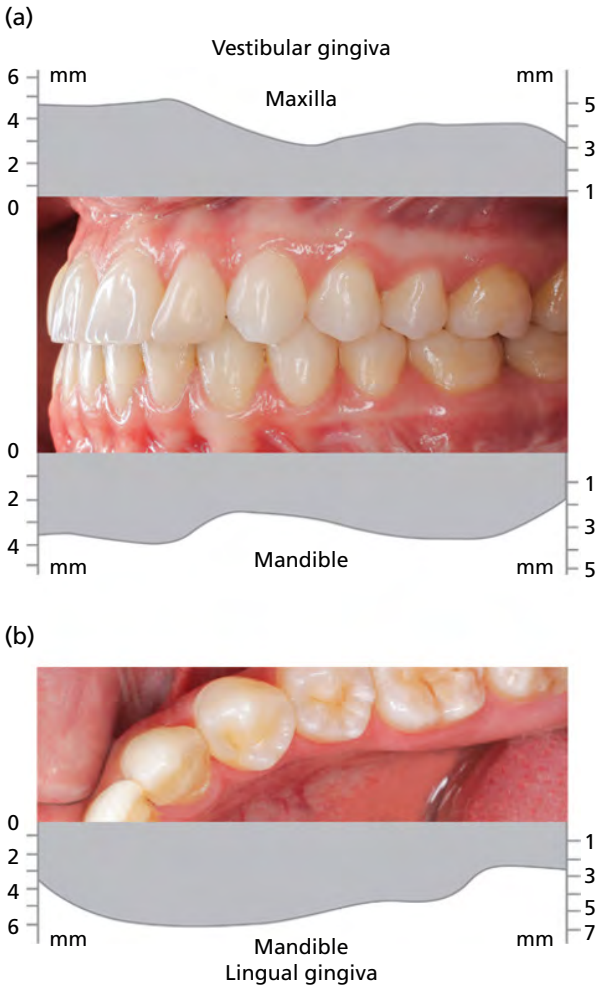


Fig. 1-12 Widths of the vestibular maxillary and mandibular gingivae (a) as well as the lingual extent of the gingiva in the mandible (b). The widths are depicted in millimeters.

age of the patients examined is depicted in Fig. 1-14 (Ainamo *et al*. 1981). The gingiva in the 63-year-olds was significantly wider than in the 40–50-year-olds. Moreover, the width of the gingiva in the 40–50-year-olds was significantly wider than that in 20–30-year-olds. This observation indicates that the width of the gingiva tends to increase with age. As the mucogingival junction remains stable throughout life in relation to the lower border of the mandible, the increasing width of the gingiva may suggest that the teeth erupt slowly throughout life as a result of occlusal wear.

Histology

Oral gingival epithelium

The dentogingival unit is schematically depicted in Fig. 1-15a. The free gingiva comprises all epithelial and connective tissue structures located coronal to a horizontal line placed at the level of the CEJ (Fig. 1-15b). The epithelium covering the free gingiva may be differentiated as follows:

- *Oral gingival epithelium*, which faces the oral cavity
- *Oral sulcular epithelium*, which faces the tooth without being in contact with the tooth surface
- *Junctional epithelium*, which provides the contact between the gingiva and the tooth.